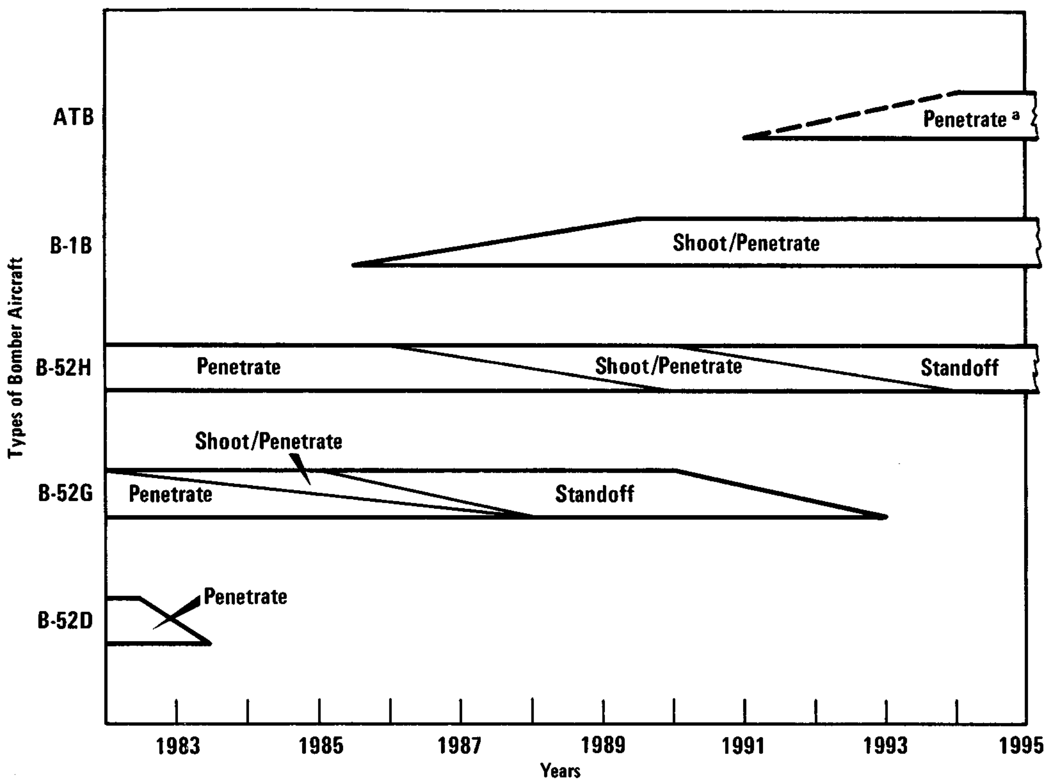
In the second phase of the modification beginning in the mid-1980s, cruise missiles are to be added internally in the B-52s bomb bays. At that time, the bombers would not carry short-range weapons that require flight in enemy airspace when Soviet air defenses are presumed to be too taxing for B-52 operations. Since these "stand-off" bombers capable of launching long-range missiles could avoid the long flight at low altitude, tanker and fuel requirements would decline substantially. Figure 3 shows the evolution in strategic bomber forces over the coming 15 years, in light of the Administration's modernization plans. Though these plans obviously can change if circumstances or policies change, they represent the general plans for modification and retirement of B-52s and introduction of the new bombers.

Figure 3.

Projected Development of U.S. Bomber Forces and Missions



[a] Projection uncertain because no precise delivery schedule for the ATB aircraft is available

SOURCE: Congressional Budget Office, based on Department of Defense Annual Report, FY 1983.

Evolving Tanker Demand in Light of Bomber Modernization

Tanker needs will increase until the end of this decade, primarily because B-52s are to be converted to carry cruise missiles and fly shoot-and-penetrate missions through the 1980s. Figure 1 therefore shows the requisite number of tankers for strategic missions over the next 14 years, in light of the Administration's modernization plans. The increasing level of tankers required is caused by the cruise missile modification to the B-52s. Bomber inventories through the mid-1980s remain unchanged. Rising tanker demand could be offset considerably with a change in the cruise missile modification program by installing cruise missiles internally and having "stand-off missions" only for B-52s. Such a program alteration has some far-reaching potential, though possibly some unacceptable military implications as well. The shoot-and-penetrate mission profile is extraordinarily taxing, increasing average tanker requirements by 34 percent for each bomber affected. In 1982, SAC would require nearly all its 615 tankers to provide aerial refueling. 2/ By 1988, this number climbs 18 percent to 713--near the peak of tanker demand--with no effective change in bomber force levels. This increase in demand could be reduced somewhat if the Air Force chose to leap-frog the shoot-and-penetrate stage when possible and fly stand-off missions entirely as soon as cruise missiles become available.

Longer-term tanker demand, however, presents an entirely different picture. As the B-1B and ATB are fielded, and the B-52s are retired from service or become stand-off cruise missile carriers only, tanker needs will decline greatly--in fact, to levels so low that current tanker capacity would be adequate (again, see Figure 1 and Table 1). This reduction is attributable to two factors: there will be fewer B-1 and ATB aircraft altogether than the current fleet of B-52s; and according to Air Force estimates of performance, the new aircraft engines will have substantially better fuel efficiency. 3/ Long-term tanker demand

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2/ SAC tanker needs would be higher because it still provides tanker support for D model B-52s. The Administration has announced its intention to retire D model bombers by fiscal year 1984. Thus, they are excluded from this analysis.

3/ Performance characteristics for ATB engines are classified. For study purposes, the ATB is presumed to have the same performance characteristics as the B-1B.

thus appears not to be substantial. This could change, however, if the Defense Department were to retain B-52s well into the 1990s, which it might do either to expand force levels or to compensate for problems with either the B-1B or the ATB. At present, however, the justification for expanding tanker capacity turns on meeting short-term shortages.

CONVENTIONAL TANKER AIRCRAFT MISSIONS--SUPPORTING THE RAPID DEPLOYMENT FORCE

Aerial refueling missions now figure prominently in Defense Department plans for a conventional NATO conflict, as well as for important non-NATO contingencies. Tankers would be used not only to support fighters and transports on the way to the theater of combat, but also in battle to augment operations of tactical fighters. With aerial refueling, fighters nearing empty but still carrying unexpended weapons can stay on station for longer periods. And in some missions, B-52s with conventional non-nuclear weapons would possibly be used. These factors could add to tanker demand.

Tanker requirements for non-nuclear contingencies cannot be estimated with the precision one can apply to strategic missions. Strategic nuclear missions are based on relatively precise and detailed plans that are not designed to be substantially altered once the attack begins. Tactical missions, on the other hand, are far less prescribed and are subjected to substantial spontaneous revision as circumstances of combat dictate.

For purposes of this study, CBO evaluated the tankers needed to deploy the Rapid Deployment Force (RDF) to the Persian Gulf via military airlift and to deliver and support tactical fighter units in theater. The Persian Gulf scenario was selected for analysis to illustrate potential conventional demand for aerial refueling for three main reasons. First, conflict in Southwest Asia--quite possibly in the Persian Gulf region--is considered a serious prospect, and use of the RDF in any such conflict is regarded as an entirely plausible scenario. Indeed, the RDF was conceived for just such a contingency. Second, any involvement of U.S. forces in a Southwest Asia conflict--a situation that would be politically highly charged--could well bring about a recurrence of the problem encountered in the 1973 Arab-Israeli war mentioned in Chapter I, namely, the refusal of nations between the United States and the Middle East to allow U.S. aircraft to land for refueling. The likelihood of this problem's repeating itself points clearly to a potential need for tanker support for a contingency involving the RDF. And third, the other main theater of possible (though less probable) conflict envisioned by the Defense Department--Europe, where a NATO-Warsaw Pact war would take place--is close enough to the United States to obviate any great need for tanker support for conventional U.S. forces except for transporting tactical fighters in the opening days of a mobilization. 4/ Though additional refueling capacity would be useful, tanker resources adequate to support the RDF as projected here would probably be sufficient to support scaled-back though essential requirements of a European conflict.

In the model used for this study, all airlift sorties using the C-5 and C-141 transports receive aerial refueling. 5/ Tankers were also used to ferry four tactical fighter wings to the theater of conflict. Those same tankers were also used to support fighter operations in theater. 6/ Rapid Deployment Forces might include strategic bombers flying non-nuclear missions too, as well as certain reconnaissance and special-purpose aircraft. Those aircraft would come from strategic nuclear force inventories. Tankers for those aircraft were included in the above analysis.

As noted in Table 1, this analysis indicates that, in the early 1980s, some 141 tankers would be needed to support the RDF in a Persian Gulf deployment, and 159 in the 1990s. The increase is caused by the addition of 50 C-5 transport aircraft to the airlift fleet, as proposed recently by the Administration. Obviously, the addition of more tactical fighter squadrons to the RDF could increase requisite tanker needs somewhat, though this

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4/ The number of tankers needed to support a full-scale NATO conflict in Europe is potentially much larger than estimated here, since there are substantially greater forces involved, especially tactical fighter wings which must be deployed across the Atlantic in the opening days of mobilization.

5/ Study results shown below presume tankers can be based at intermediate staging areas, which is a frequent study parameter. The CBO model can evaluate restrictions that limit tanker basing to U.S. or theater fields as well.

6/ The commander of the Rapid Deployment Joint Task Force has indicated that as many as four tactical fighter wings would accompany RDF operations.

estimate appears reasonable to support current levels of conventional demand in a Persian Gulf contingency. As displayed in Figure 1, in the long term, current tanker resources would be adequate to support both strategic and conventional operations. In the interim, however, the shortage of tanker resources implies that the Defense Department will, over the next five years at least and maybe for longer, face a difficult trade-off, if conditions should arise that necessitated use of tankers for conventional operations. Those tankers become available only at the potential expense of strategic missions.

TANKER SHORTAGE AN ISSUE OF TIMING

The problem of tanker "shortages," then, is a timing issue; tanker modernization alternatives should therefore be evaluated in this context. Obviously, the Congress could judge that it is willing to accept the risk presented by these tanker shortages, and choose not to expand tanker resources, saving substantial expenditures over the next five years. That course is unlikely, however, since the Congress has of late been instrumental in boosting tanker improvement programs. For the most part, those programs preceded the recent bomber modernization effort, however. Not all alternatives may thus be required, and with different modernization objectives, some alternatives may be more appropriate than others. This is the subject of the concluding chapter.

CHAPTER III. ALTERNATIVE APPROACHES TO MODERNIZING TANKER FORCES

The Air Force has three options for expanding the size and effectiveness of its tanker aircraft fleet:

- o Installing newer generation CFM-56 engines on existing KC-135s;
- o Installing older generation JT3D engines on KC-135s; or
- o Continuing to buy KC-10 advanced tankers.

As a guide for considering what course the Congress might take concerning the tanker fleet, this chapter evaluates the relative effectiveness of these options. It concludes with three strategies for meeting future tanker needs.

PERFORMANCE IMPROVEMENTS WITH TANKER MODERNIZATION ALTERNATIVES

The most widely used method for comparing tanker alternatives is by their respective fuel delivery capacities. It is on this basis that Air Force spokesmen have indicated that the CFM-56 turbofan engine improves performance of the KC-135A tanker by 50 percent, that the JT3D engine by 20 percent, but that the KC-10 aircraft is three times better than a current KC-135A. The Air Force estimates are based on the fuel delivery capacities at a specific hypothetical distance. Such a single measure, however, fails to account for the ranges and diversity of types of missions and the operating conditions and restrictions that can affect tankers' relative performance.

Using the computer model and scenarios developed by CBO (described in the previous chapter and Appendix A), the analysis here goes beyond fuel delivery capacities to evaluate the three tanker alternatives. On the basis of specific flight and fuel performance data provided by the Air Force, each tanker was "flown" in all missions in support of all types of receiver aircraft, subject to the same assumptions and restrictions used to establish overall tanker demand. This method of analysis not only permits direct comparison of three tanker alternatives; it also indicates the incremental (or "marginal") contributions of additional modified tankers.

Table 2 compares the average performance improvements based on the method used by CBO to the Air Force estimates of performance. The CBO estimate is based on use of each respective tanker in all types of missions over each of the 14 years of this study period with the force structure likely to be in place as noted in the previous chapter. Figure 4 shows the year-by-year average effectiveness of the three alternatives. 1/ This analysis reveals several major points.

TABLE 2. CURRENT TANKER AND THREE ALTERNATIVES--AIR FORCE AND CBO MEASURES OF IMPROVED TANKER PERFORMANCE

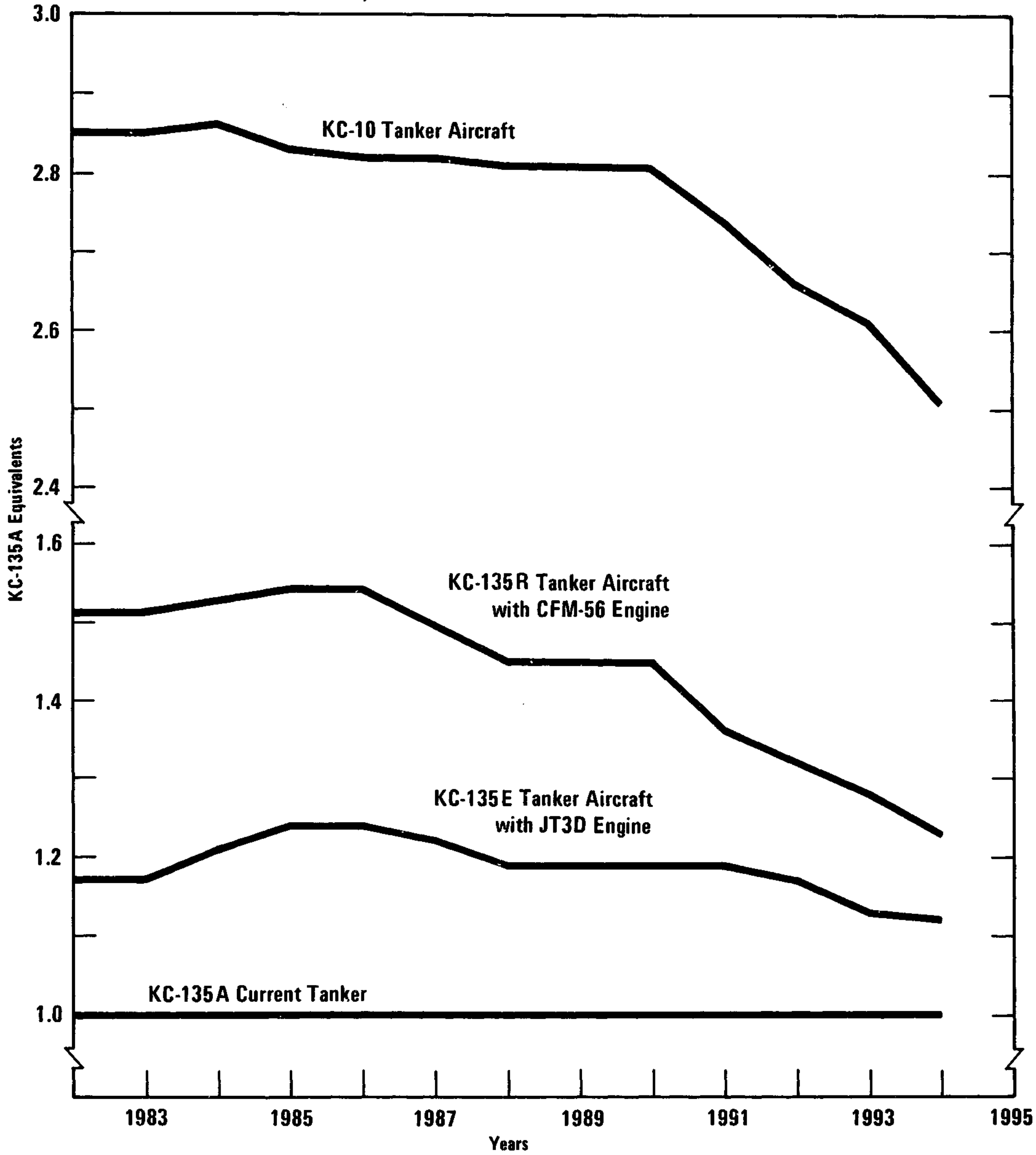
Tanker	Air Force	CBO Analysis
KC-135A (Current Tanker Aircraft)	1:1.00	1:1.00
	(Improvement Ratios)	
KC-135R Aircraft with CFM-56 Engine	1:1.50	1:1.43
KC-135E Aircraft with JT3D Engine	1:1.20	1:1.19
KC-10 Aircraft	1:3.00	1:2.76

SOURCE: U.S. Air Force and Congressional Budget Office.

NOTE: Improvements expressed in KC-135A equivalents.

1/ The curves are hypothetical, since they presume all missions are flown by that single type of aircraft that year.

Figure 4.
Year-by-Year Performance Improvement of Tanker Aircraft Alternatives (In KC-135A Equivalents)



SOURCE: Congressional Budget Office.

Average Performance Improvements

First, according to CBO's evaluation, all the alternatives listed at the outset of this chapter are likely to fall short of the Air Force's performance improvement estimates. As noted above, Air Force claims for each alternative are based on comparison of fuel delivery capacities. The CBO analysis, by introducing specific (though hypothetical) missions and controlling for the anticipated development of the bomber force, indicates that improvement would be somewhat less if tankers are flown in the full range of likely missions and subjected to specific operating restrictions.

Second, although the table indicates the average performance over the 14-year projection period, the figure shows that there is a definite trend among all tankers for performance under all three types to decline in relative terms. This is the direct result of the evolution of the bomber force, with the gradual retirement of less fuel-efficient bombers (less fuel-efficient receivers boost the utility of tankers) and the introduction of the somewhat more fuel-efficient ones. Through the early- to mid-1980s, the CFM-56 is expected to perform as well as Air Force estimates or better. The relative utility of the CFM-56 diminishes, however, as B-52s retire and a newer, smaller, and more efficient fleet of bombers is fielded. The bulge in the JT3D curve in Figure 4, between 1983 and 1988, is directly related to the B-52's use in shoot-and-penetrate missions, which are particularly demanding in terms of tankers and for which the JT3D is well suited. At the end of the study period, the relative utility of the JT3D declines dramatically.

"Marginal" Contribution of Tanker Alternatives

This phenomenon of declining relative utility is particularly important, since fielding new or modified tankers will take a number of years. Indeed, current modification programs produce no substantial numbers until near the end of this decade when, in relative terms, the tankers would be substantially less useful than if they had been available earlier in the decade. As such, it is particularly important to examine the marginal effect of adding further increments of tanker capacity.

The CBO's marginal analysis indicates that the greatest utility for tanker modernization is over the next six to eight years. For this analysis, CBO examined marginal effects for two critical years--1988, at the peak of tanker demand and utility, and 1994, when B-52s would be retired and the new generation of bombers operational. Table 3 shows the marginal utility of adding successive increments of 50 re-engined tankers of the two types considered in these two important years. Both tanker types appear to perform much better in 1988 than in 1994, as also indicated in Figure 4. For the CFM-56 alternative, up to 250 tankers offer 50 percent performance improvement or better in 1988. In 1994, however, only the first 50 would offer that performance. The relative utility of the remaining 250 tankers would decline substantially. The same, though more extreme, effects hold true

TABLE 3. TANKER RE-ENGINING OPTIONS--MARGINAL IMPROVEMENT OF SUCCESSIVE INCREMENTS OF RE-ENGINED AIRCRAFT (In percentage improvement per tanker per increment)

Increments of Modified Aircraft	CFM-56 Engine		JT3D Engine	
	1988	1994	1988	1994
1-50	67	50	33	25
50-100	67	33	33	20
100-150	55	30	25	20
150-200	50	25	25	15
200-250	50	25	25	a/
250-300	33	10	20	a/
300-350	33	a/	20	a/
350-400	33	a/	20	a/
400-450	28	a/	10	a/

SOURCE: Congressional Budget Office.

a/ In terms of fuel delivery, there is no effective improvement over KC-135As.

for the JT3D. Indeed, if the program is designed to meet 1994 requirements only, there is no apparent performance advantage for re-engining more than 200 tankers with JT3D engines.

COST EFFECTIVENESS OF TANKER ALTERNATIVES

The performance improvement comparisons shown in Tables 2 and 3 present only part of the story, because the costs of the alternatives vary dramatically. Table 4 shows the cost effectiveness of the three alternatives--that is, the cost to provide one KC-135 tanker equivalent. Table 5 shows the total "life-cycle" costs of providing 100 KC-135A tanker equivalent capacity. Since all three alternatives have greater capability than the current

TABLE 4. INVESTMENT COST OF ADDITIONAL TANKER EQUIVALENTS (Based on average improvement of alternatives)

		In millions of 1983 dollars	
Option	Average Improvement (percent)	Average Investment Cost	Investment Cost per Tanker Equivalent
KC-135R Aircraft with CFM-56 Engine	43	20.0 a/	46.5
KC-135E Aircraft with JT3D Engine	19	7.2 a/	37.9
KC-10 Aircraft	276	70.0 b/	25.4

SOURCE: Congressional Budget Office.

a/ Includes funds to update subsystems not essential for the engine refit but necessary to keep the aircraft operational over the next 20 years.

b/ Includes approximately $4 million for features to make the aircraft acceptable for strategic missions, such as hardening against electromagnetic pulse.

TABLE 5. LIFE CYCLE COSTS OF PROVIDING 100 KC-135 EQUIVALENTS

	(Billions of 1983 dollars)			
Tanker	Number of Tankers	Investment Costs	Operating and Support Costs a/ (20 years)	Life-Cycle Costs a/ (20 years)
KC-135A Aircraft	100	0.2	4.3	4.5
KC-135R Aircraft with CFM-56 Engine	70	1.5	2.6	4.1
KC-135E Aircraft with JT3D Engine	84	0.6	3.2	3.8
KC-10 Aircraft	36	2.5	2.3	4.8
KC-10 (Equal Flying Hour/ Crewing as KC-135)	36	2.5	1.2	3.7

SOURCE: Congressional Budget Office

a/ Based on 326 flying hours per year for KC-135R and E and 540 flying hours per year for the KC-10. The KC-135 is currently manned at levels--1.27 crews per aircraft--necessary to support strategic missions. The KC-10, however, will have three crews, necessitating a higher level of flying hours for training purposes.

tanker, fewer are needed to provide "equivalent" capacity. In terms of investment, the most cost effective way to expand tanker resources is by purchasing KC-10 advanced tankers.

Table 5 shows two entries for the KC-10. The first assumes KC-10 operations as currently planned, having three crews per aircraft and 540 flying hours per year. All versions of the KC-135 have 1.27 crews and 326 flying hours. If the KC-10 is compared with comparable assumptions, life-cycle costs are slightly lower than costs for the re-engined KC-135s. In life-cycle cost terms, the CFM-56 and JT3D options are roughly equal. The higher investment cost of the CFM-56 is offset by expected operating savings.

Though these measures of costs and effects are useful as general guides, the tanker alternatives have different costs and effectiveness, depending on when they are implemented. Thus, the chapter concludes with three specific strategies that might be adopted as tanker modernization plans.

ALTERNATIVE TANKER FLEET MODERNIZATION STRATEGIES

Option I. The Administration Program

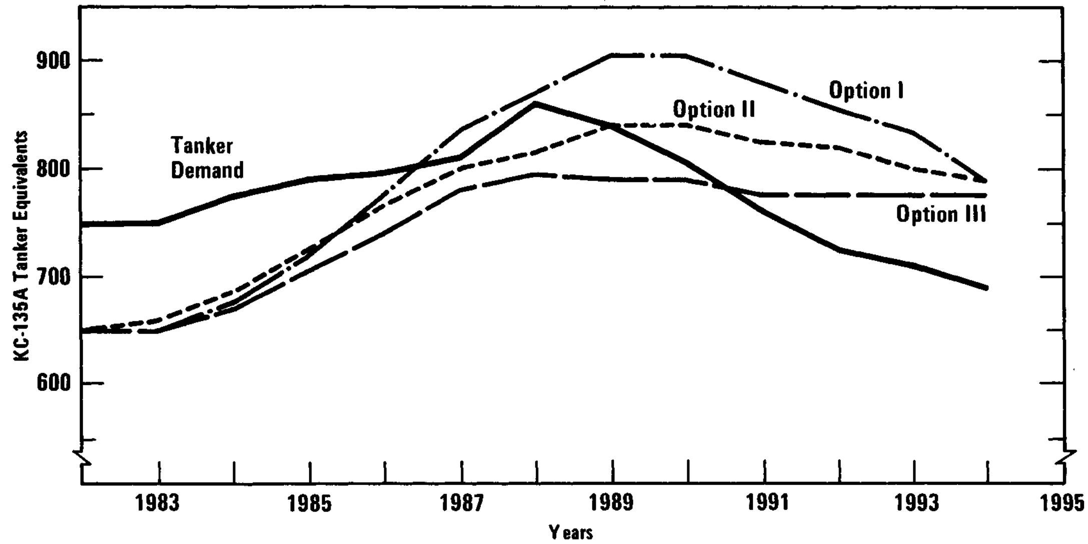
The Administration has announced its intention to proceed with re-engining a portion of the existing fleet of KC-135 tanker aircraft with the CFM-56 engine as the primary means to meet future tanker needs. It has also announced its intention to purchase an additional 44 KC-10 transports, but to use them primarily to supplement airlift resources. Since the KC-10 was sought initially as a tanker, it will be purchased with these features intact, and will have crews trained in aerial refueling procedures, the KC-10 is evaluated here for its potential as a tanker. Table 6, a summary of the costs of the three options, shows the procurement profile for both programs, which together cost $8.5 billion over the next five years.

Figure 5 shows the estimated effect of the Administration tanker modernization program in meeting expected tanker demand. The Administration's program would fall short of meeting tanker demand in the early- to mid-1980s, meeting projected tanker needs only by 1987. In the 1990s, when requisite tanker needs begin to lessen, capacity will substantially exceed demand.

If the Administration carries out its program over the next five years and refits 300 KC-135s with CFM-56 engines, further re-engining would not be needed. (See Figure 5, which depicts the effects of the three modernization options shown in Table 6 with respect to projected demand.) This is because the modified tankers would become available only after tanker demand drops in the 1990s. Air Force spokesmen have already announced their goal of re-engining the entire fleet of 615 KC-135s, however. (That is not currently an official policy of this Administration.) As Figure 5 implies, extending the Administration's program beyond 300 would provide substantial excess capacity in the 1990s. Some

Figure 5.

Projected U.S. Tanker Aircraft Demand and Alternative Modernization Options, 1982-1995



SOURCE: Congressional Budget Office.

of that excess capacity could be used profitably, as an extra margin of flexibility for both bombers and tankers, and as a hedge against future improvements in Soviet air defenses. It could also be held in reserve in the event of additional contingency operations, such as simultaneous NATO and Persian Gulf conflicts (what the Defense Department terms a one-and-one-half-war scenario), though the precise implication and plausibility of such developments is quite uncertain. Also, should problems develop in production and delivery of B-1B bombers, B-52s could be retained for longer periods, lengthening the period of high demand for tanker support.

To reduce excess tanker capacity, the Defense Department could choose to retire unmodified tankers starting in 1990. Retiring excess tankers could result in substantial savings, especially in terms of life-cycle costs, since the cost of operating a tanker for 20 years is estimated to reach $43.2 million in fiscal year 1983 dollars.

TABLE 6. UNIT PURCHASES AND PROGRAM COSTS FOR ALTERNATIVE TANKER MODERNIZATION PROGRAMS

Cost Component	Through 1982	1983	1984	1985	1986	1987	Total
Option I--The Administration Program							
Procure KC-10 Aircraft	18 a/	8	8	8	8	10	60
Refit KC-135 Aircraft with CFM-56 Engine	9	25	58	64	72	72	300
Cost (billions of 1983 dollars)		1.47	1.84	1.80	1.78	1.57	8.45
Option II--Lower Cost Modernization							
Procure KC-10 Aircraft	18 a/	8	8	8	8	10	60
Refit KC-135 Aircraft with JT3D Engine	28	48	48	48	13		185
Cost (billions of 1983 dollars)		1.18	0.85	0.80	0.53	0.41	3.77
Option III--Procure KC-10 Aircraft Only							
Procure KC-10 Aircraft	18 a/	12	12	12	6		60
Cost (billions of 1983 dollars)		1.13	0.76	0.65	0.27		2.81

SOURCE: Congressional Budget Office.

a/ Assumes the Congress endorses the Administration request for two KC-10s in the fiscal year 1982 supplemental appropriation.

Option II. Matching the Administration Program Performance at Lower Cost

The previous section of this chapter noted that the JT3D engine, while less capable than the CFM-56 alternative, is dramatically more cost effective. It also indicated that both re-engining alternatives would become much more useful in the mid- to late-1980s, when tanker demand is projected to peak. The Congress could choose to re-engine the KC-135 with the JT3D engine, almost matching the Administration program in terms of meeting tanker needs, yet saving an estimated $4.7 billion over the next five years. This option would re-engine 185 KC-135s using older generation JT3D engines, and would cost $3.8 billion over the next five years--less than half the $8.5 billion cost of the Administration program.

This alternative would provide the capabilities of Option I through 1986 (see Figure 5). After 1986, the performance of the two options would diverge, but this is after the point when either choice could largely meet the demands of the scenarios studied here. These performance differences could be important if the B-1 is delayed, causing B-52s to be kept in service longer, requiring more tanker support than is shown in Figure 5. Similarly, should conventional non-nuclear demand for tankers be greater than projected here, the differences in performance might be significant. If Air Force production plans hold, however, after 1990, either alternative is projected to provide sufficient capacity to meet estimated demand. Although this alternative fails to meet the tanker shortfall in the early to mid-1980s, it provides nearly as much capacity as the Administration's alternative.

Critics of the JT3D alternative have questioned the availability of salvaged aircraft for use by the Air Force. The House Committee on Appropriations indicates that, of the more than 400 commercial 707s currently in service, some 200 are estimated to become available for salvage over the next five years--the number this option would require. Indeed, if noise and air pollution regulations remain in force, none of the 400 707s with JT3D engines would be permitted to operate in U.S. airspace after 1985. This should improve prospects for obtaining used aircraft, because they could not be used in commercial service.

Critics have also noted that the condition of the used planes' engines is uncertain. The Air Force actively explored opportunities to purchase some 96 used 707s from commercial U.S.

carriers, almost half the aircraft needed under this option. Maintenance records and standards on those aircraft have been examined, leading Air Force spokesmen to declare the planes usable. All engines could be refurbished at modest costs (which have been included in the calculations for this option). It might prove more expensive to refurbish aircraft engines beyond the original 96 proposed earlier by the Air Force. That higher cost would probably be offset by the likely lower selling price for the aircraft as they approach the 1985 air and noise pollution deadline. This option provides for purchase of 185 aircraft, 89 more than originally sought by the Air Force. But 85 of the aircraft would be purchased on or after the 1985 deadline, when costs should be low indeed.

It should be noted that the JT3D engine does not provide the full potential performance that the CFM-56 does. Neither does it offer the noise and air pollution abatement advantages. (See footnote 3 in Chapter I.) Though this alternative has somewhat less capacity than the Administration's plan, it is dramatically less expensive.

Option III. Limit Tanker Modernization to KC-10 Procurement

The most effective way to expand tanker capacity quickly is by purchasing additional KC-10 advanced tankers. Indeed, Administration plans to purchase 44 more KC-10s would provide as much tanker capacity as re-engining 300 KC-135As with the more capable CFM-56 engine. As far as the JT3D re-engining program is concerned, the Air Force would have to re-engine the entire tanker fleet with JT3D engines to match the tanker capacity increase provided by the 44 KC-10s. An all-KC-10 alternative would satisfy between 85 and 95 percent of projected tanker needs through the mid-1980s.

The Congress could decide that it is willing to meet the bulk of tanker requirements by proceeding with the KC-10 program and cancelling further re-engining. This would save $5.7 billion over the next five years relative to Administration plans.

Though the KC-10 alternative is potentially a very satisfactory aircraft for use in SAC's conventional non-nuclear war plans (such as to support the RDF in a Persian Gulf contingency), the Air Force insists that the aircraft, as currently outfitted, does not meet SAC's requirements for strategic warfare. Since the KC-10 was purchased primarily for conventional operations, the Air

Force chose not to install certain features that SAC considers essential--such as "hardening" aircraft systems against certain effects of nuclear blasts. The CBO has assumed the cost of those additional features at $4 million per aircraft (certain other analysts would set this figure higher) and included that sum in the purchase prices shown here, to ensure that the aircraft hypothesized for the analysis could be useful for strategic as well as conventional operations.

Critics of this option might also note that, more than the first two approaches, this one relies heavily on the KC-10s. Yet the KC-10s are being bought primarily as cargo aircraft, and so some or all of them might not be available for tanker missions. The first two options clearly compensate more for the lack of the KC-10s. But the KC-10s are very capable tanker aircraft with crews that will be trained in aerial refueling. Thus it seems reasonable that, in crises for which tankers are in short supply, many of the KC-10s will be made available for tanker duties. Either other aircraft or sealift assets would be used to convey needed military cargo.

APPENDIX

APPENDIX A. STUDY METHODOLOGY AND SCENARIOS USED IN CBO ANALYSIS

To conduct this study, the Congressional Budget Office developed a series of computer models to determine aerial refueling requirements for aircraft that fly strategic nuclear and conventional non-nuclear missions. The model, called EXPONENT, was developed in conjunction with the University of California's Graduate School of Public Policy at Berkeley. This appendix describes the model in general terms and specifies the assumptions underlying the scenarios used to evaluate tanker performance and demand.

THE EXPONENT MODEL

The EXPONENT model consists of standard equations for computing fuel consumption, together with non-linear programming to determine optimal refueling distances and combinations of tanker and receiver aircraft. Appendix Figure 1 schematically diagrams the model.

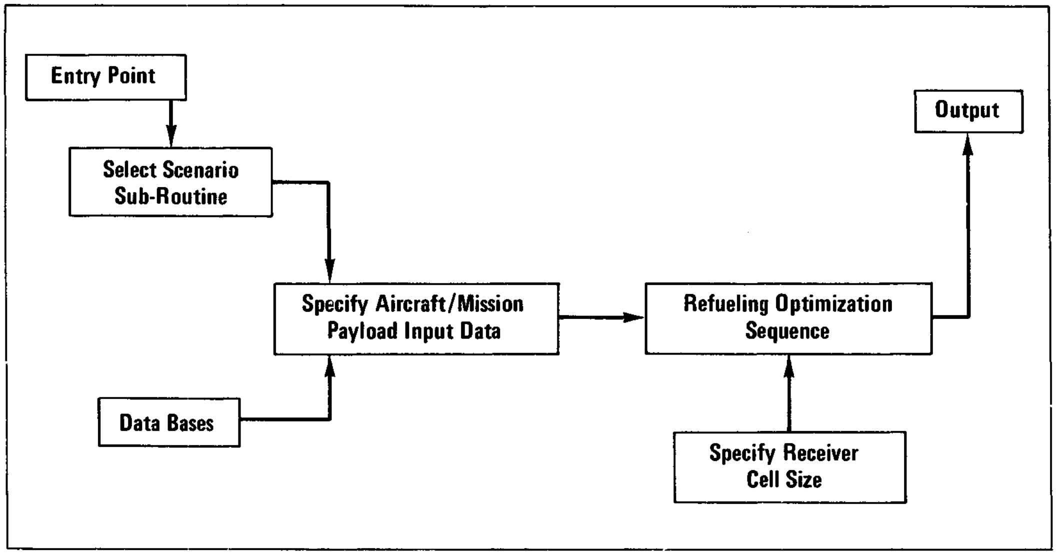
The model's algorithms use Breguet range equations to compute fuel consumption. The equations calculate fuel consumption on the basis of specific factors, including the thrust of the engines, the air resistance of the aircraft (specifically, the lift-to-drag coefficients for the aircraft), the cruising altitude, and so forth. Variables for the equations were derived from data provided by the Air Force for each of the aircraft types examined.

The heart of the model consists of "optimization routines" using non-linear programming techniques. Given specific mission characteristics--such as overall distances, low-altitude distances within enemy airspace, and cruising altitudes--the optimization routine determines fuel reserves needed to accomplish full missions, the best combination of tankers and receiver aircraft, and the distances at which aerial refuelings take place.

The model uses standard Air Force assumptions about payloads, take-off weights, fuel reserve requirements, tanker recovery distances, and so forth. All variables can be changed. CBO conducted checks on all variables to determine the degree to which results were sensitive to specific model assumptions. The model is written in APL.

Appendix Figure 1.

EXPONENT Model Flowchart



SOURCE: Congressional Budget Office.

STRATEGIC MISSION SCENARIO

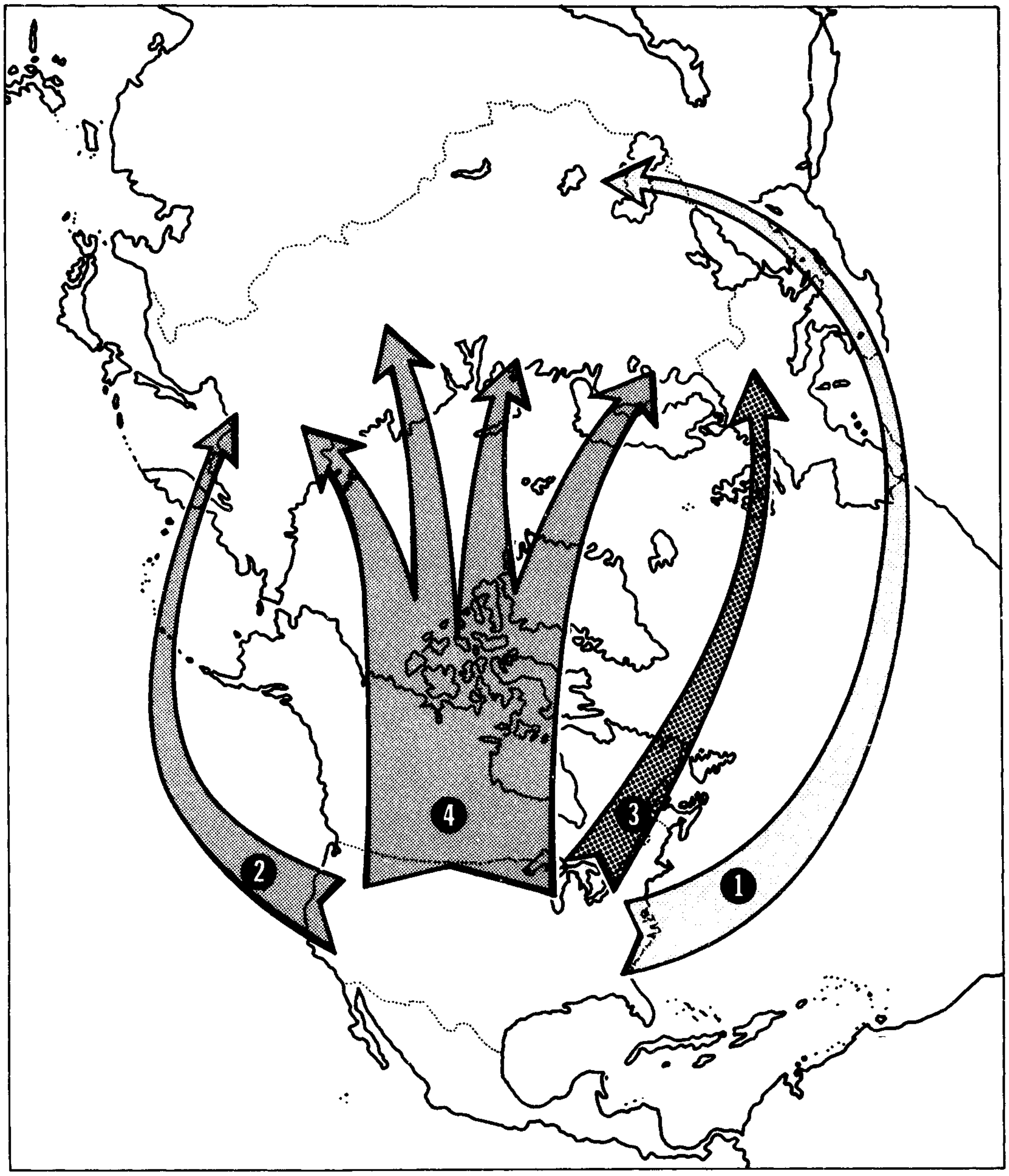
As discussed in Chapter II, the Strategic Air Command is responsible for developing the Single Integrated Operational Plan (SIOP), which contains detailed plans for each strategic nuclear missile and bomber, as well as tanker and other support equipment and units. The SIOP obviously is not available for public discussion. As a substitute, CBO developed a hypothetical scenario for attacking the Soviet Union with bomber aircraft (see Appendix Figure 2). The arrows in the figure represent four generic attack missions:

Mission 1. Bombers fly over the Mediterranean, attacking southern Soviet targets, and return to Turkey;

Mission 2. Bombers fly over the Pacific to attack Pacific Soviet targets, recovering in South Korea and Japan bases;

Appendix Figure 2.

Hypothetical Attack Missions Used in CBO Analysis of Tanker Aircraft Modernization Alternatives



SOURCE: Congressional Budget Office.

Mission 3. Bombers fly over the North Atlantic to attack Soviet targets in eastern Europe and western Asia, with bombers recovering to western European airfields;

Mission 4. Bombers fly over the North Pole to attack central Soviet targets, recovering to unspecified southern airfields.

Specific mileages and flight profiles were associated with each of these attack missions. Bombers were assigned to these missions according to the proportion of targets assumed in each region. Target weighting was based half on industrial concentrations (with population serving as surrogate data) and half on density of enemy military installations. The weighting of the shaded arrows on the figure reflect the relative proportion of bombers assigned to the above missions. By far the highest concentration of targets is found in Mission 3. This study does not specifically allocate bombers by the type of weapon they carry, but allocates them strickly based on numbers of warheads.

It is important to note that this CBO scenario is not based on the SIOP, nor is it intended to shadow it in such terms as targets, options, or attacking aircraft. The scenario is merely designed to provide a general but realistic yardstick for measuring levels of tanker demand and for comparing the performance of alternative tankers.

CONVENTIONAL MISSION SCENARIO

As described in Chapter II, this study evaluated the potential tanker needs associated with a conventional non-nuclear mission involving the Rapid Deployment Force in the Persian Gulf region. The analysis assumed that the RDF consisted of the 18th Airborne Corps and the 24th Mechanized Infantry Division. In addition, the RDF hypothesized by CBO included four tactical fighter wings. The specific designation of units in the RDF was deemed necessary only to determine average payloads for the transports and to establish notional distances for airlift missions. The results in no sense presume "optimality" in deployment.

This scenario assumed that U.S. tankers could stage from intermediate bases, for example at Lajes Field in the Azore Islands. The scenario assumed that 70 (PAA) C-5 and 234 (PAA) C-141 aircraft receive aerial refueling on all outbound sorties.

During the later half of the 1980s, this fleet is assumed to expand to include an additional 45 (PAA) C-5 transports. Those tankers that transport tactical fighters to theater are used exclusively to support those same fighters in theater.

As with the CBO substitute for the SIOP, it should again be noted that the RDF could consist of units other than those specified here. For example, the RDF might include B-52s carrying nonnuclear munitions, as well as intelligence and reconnaissance aircraft requiring tanker support. Those aircraft, including the special-purpose aircraft, are considered under the strategic scenario discussed above. If they are used in an RDF mission in the Persian Gulf scenario, theoretically, they would release tankers, which would no longer be needed in strategic missions; these could accompany them and provide support for conventional operations. As such, while they might well accompany the RDF, they are included in this study in the strategic nuclear scenario and, to avoid double counting, are not specifically denoted here.

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